BALD MOUNTAIN GOLD MILL
Lead Vicinity Nevada Gulch at the head of False Bottom Creek
Lawrence County
South Dakota

HAER No. SD-2

HAER
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HISTORIC AMERICAN ENGINEERING RECORD

BALD MOUNTAIN GOLD MILL HAER No. SD-2

Location:	Nevada Gulch at the head of False Bottom Creek, four miles west of Lead, Lawrence County, South Dakota.
Dates of Construction:	1907-59.
Present Owner:	Wharf Resources.
Present Use:	Unused.
Significance:	The technology used at Bald Mountain Gold Mill provides an excellent illustration of the development of the cyanide process of gold milling in the first half of the twentieth century. Historically this site was of great economic and social importance to the Black Hills region of South Dakota.
Historian:	David Eve
Project Information:	This recording project is part of the Historic American Engineering Record (HAER), a long range program to document historically significant engineering and industrial works in the United States. The HAER program is administered by the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER) Division of the National Park Service, U.S. Department of the Interior. The Bald Mountain Gold Mill recording project was co-sponsored during the summer of 1992 by HABS/HAER, by Wharf Resources, a Montana general partnership, and by the South Dakota Historical Preservation Center, State Historical Society, through the Historic Preservation Fund of the U.S. Department

of the Interior.

The fieldwork, measured drawings, historical reports, and photographs were prepared under the direction of Eric N. DeLony, Chief of HAER. The recording team consisted of Robert W. Grzywacz, Architect, Team Supervisor; and Albert Aflenzer, Architect, US/ICOMOS, Technical University of Vienna; Virginia Brumback, Architect, University of Washington; and Leeann Jackson, Architect, University of Pennsylvania. The historical report was produced by David Eve, US/ICOMOS, Ironbridge Institute. Formal photography was done by Joe Eliot.

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CHAPTER ONE: INTRODUCTION

Bald Mountain Gold Mill lies approximately four miles west of Lead, in the Black Hills region of South Dakota. Bald Mountain itself is southeast of the mill complex, which is set on the side of a hill, facing north and looking towards the bed of False Bottom Creek. For much of its operating life Bald Mountain mill was the second largest producer in the Black Hills, surpassed only by the Homestake mine. During the period from 1906 until 1959, it grew to be the center of an industrial complex that included numerous mines, transportation facilities and the workers' town of Trojan. Although the primary purpose of this project is to record the physical remains of the Bald Mountain mill, interpretation and analysis of documentary sources and oral testimony are vital to constructing a picture of the mill as an operational plant.

Looking at the development of the Black Hills gold field during the period 1876-1906 reveals the origins of trends impacting upon the establishment and early operation of the mill. Focus on the Bald Mountain district from 1906 until 1959 shows the regional change precipitated by the growth of large companies capable of greater investment in more permanent plants serving substantial numbers of mines. The formation of the Trojan Mining Company at Bald Mountain in 1910 is a typical example of this and is an important part of the mill's history. Discussion of the mill's owners is also important to illuminating the relationship between events on site, and their economic fortunes and policies. These personal factors caused the mill to develop from a small independent facility, reliant on sub-contracted "custom" work, to the center of a technically innovative and fully integrated industrial complex.

The technical development of the Bald Mountain mill is also discussed in the context of gold milling in general. Chapter Five, "The Development of Gold Milling Technology" serves as a preface to the technical history of the mill, illustrating important continuities in spite of technological change. It is useful to apply this information to the data yielded by the recording process. The majority of the extant machinery and processing facilities date from the last phase of operation (1934-59), but much of the plant pre-dates this and some of the structure survives from the earliest phase.

The opportunity presented by recording the Bald Mountain gold mill represents more than documenting a decaying site. Bald Mountain Gold Mill holds great regional significance and is a first class example of its type. Here we find evidence to illustrate the practice of gold milling over a half century and the development of technical processes during that period.

CHAPTER TWO: THE BLACK HILLS GOLD FIELD IN THE 19TH CENTURY

Reports from miners and geologists on Custer's 1874 expedition to the Black Hills gave official confirmation to reports of gold deposits in the hills. For the next two years, the army attempted to protect the Indian-owned hills from prospectors while demand for entry to the gold fields grew. When negotiations to purchase the Black Hills and/or its mineral rights from the Sioux broke down in 1876, the army withdrew and a gold rush ensued. Gold camps were established quickly at Custer, Lead, Deadwood and Hill City, while 'Hay Town' to the east of the Hills, (later Rapid City) became the major supply center for the region. The two principle road links to the hills were from Fort Pierre to the east, and from Bismark, North Dakota, where the Northern Pacific Railway had its terminus. The railroads were of vital importance, bringing labor and supplies such as mining machinery to the remote region. The Chicago and North Western constructed a line to Pierre, and the Chicago, Milwaukee and St Paul reached Mitchel, both in 1880. The first railroad to the hills was the Fremont, Elkhorn and Missouri Valley Railroad (later part of the Chicago and North Western) which reached Buffalo Gap in 1885 and Rapid City the following year.

The first wave of gold prospectors worked the placer gold, gold eroded from the surrounding rock and deposited in gravel found in creek beds. Although groups of miners would sometimes co-operate to work large water sluice systems or extensive claims, the gold rush period was essentially characterized by small groups working low cost sites. Many claims were staked on underground deposits of hard rock ores early in the gold rush but most remained undeveloped due to the easier profits to be made from the placer sites and the low levels of capital available to the prospectors. Claims on gold bearing quartz rock had already reached considerable numbers by the end of 1876: 147 in the Deadwood area and 70 around Custer. Once underground working started in earnest, production quickly outstripped that of the rapidly diminishing placer resources. The early hard rock mines brought a second boom to the towns of the southern Black Hills while new towns, such as Rochford, grew up on the previously unexploited mine sites.[1]

The processing of the ore from hard rock mines was undertaken in mills, larger and more specialized facilities than the elementary technology of the placer operations. Many small, independently owned mines were unable to find the capital to construct mills that could operate at a cost effective scale and yield large profits from the relatively expensive underground workings. An alternative was to send the ore out to `custom' mills, subcontracted to do the processing. The Hidden Treasure mine, near Central City, was established in 1876, and successfully processed its ore through a custom mill. An attempt to install milling facilities of its own only served to erode profit margins and bring the company into financial difficulties.

As the size of mining operations expanded outside investment became an important factor. Capital was forthcoming from local banks, businessmen in established mining regions, such as California, and the industrialized East. The Homestake mine was initially financed by a Deadwood merchant and a ten stamp mill was built, but it was investment from California that brought an eighty stamp mill and set the mine up as a large scale producer. By 1878, over $1,000,000 of California capital had been invested in the Black Hills.

As the scale of hard rock mining increased, there was a parallel decline in reserves of "free milling" ores (those from which gold and silver could be removed by simple milling techniques). The resulting move towards the working of deeper refractory ores - whose metal content was held in complex and hard to dissolve chemical bonds - required the construction of new mills using the techniques of chlorination and cyanidation. With correspondingly rising overheads, both in the mines and in the mills, the small, independent mines began to be consumed by large corporations financed from outside the region.

CHAPTER THREE: THE BALD MOUNTAIN MINING DISTRICT

The Bald Mountain district had been worked during the initial gold rush in 1877-78 when prospectors centered their interest on the Empire, Des Moines, Huxley, Golden Bubble, Decorah, Lady Elgin and Magnolia claims. The Decorah, Lady Elgin and Empire mines were opened during this period, but these early ventures were poorly financed and suffered from an inability to process Bald Mountain's refractory ores profitably.[2] Bald Mountain mining subsequently shifted from individually owned efforts to large, well-financed companies owning multiple mines and often constructing their own mills. Although this trend may be discerned in the 1890s, numerous small mines continued to operate for some time, making the region a curious patchwork of mining operations. From this consolidation several dominant companies emerged. By 1920, these companies had combined to give the Trojan Mining Company and its successor, the Bald Mountain Company, dominance in local gold mining.

The Portland Mining Company was one of the earliest and most important to work the Bald Mountain district. By amassing considerable amounts of property and capital, it served as the launchpad for the later Trojan and Bald Mountain companies. The Portland Mining Company was formed in 1879 when the Portland, Gustavus and Paragon claims were purchased by Ankeny and Co. of Clinton, Iowa. A mill was constructed and was operational by the end of 1879, drawing water from a mine at Squaw Creek. The company came under new ownership in 1883, under the name of The Portland Consolidated Milling and Mining Company, with George M. Curtis of Clinton, Iowa as president. The mill was fitted with new machinery for a more profitable level of recovery, earning approximately $20 per ton of ore. However these efforts proved to be insufficient and by 1886 ore was being shipped out to Rapid City for more cost effective custom milling.

In 1884, the Portland Company purchased the Trojan mine. The Trojan claim had been staked in 1877 and was being worked in conjunction with the Empire and Perseverance mines by 1879. These three, together with the Folger, Oliver and Indispensable mines were purchased by successive English and Boston- based companies in 1881 and 1882 before finally being taken over by the Portland Consolidated Company in 1884.[3] In 1890-91 the Fremont, Elkhorn and Missouri Valley Railroad extended its track from Deadwood to the Portland mine, and large quantities of ore were sent to Omaha, Nebraska for custom processing despite attempts to improve the operation of Portland's own mill. Portland and Trojan mines also sent some ore to the Deadwood and Delaware Company's smelter in Deadwood.

The Decorah mine, working a claim that was staked in 1878 and sending its ores to a custom mill, was purchased by the Portland in 1900 while the Clinton mine also came under the same management. The Clinton had operated independently since 1879, and when incorporated as the Clinton Mining Company in 1890 owned seven claims, including the Leopard, Jessie Lee, and Ashland. The 1900 takeover additionally brought the Rosenthal, Ajax and Burns properties into the Portland company.[4] Both Clinton and Portland mines were run by the same management and ore was transported out from a tunnel on the Empire State claim.

Ore from the properties of the Portland companies was taken to a succession of custom mills during the early years of the twentieth century. Recently constructed cyanide mills at Deadwood and Spearfish were utilized as well as the American Milling and Smelting Company's facility in Kansas City. In addition, a fifty-ton per day cyanide plant at Gayville in the Black Hills was purchased from the Boston and South Dakota Mining Company. In 1906 ore from the Portland and Clinton mines was being taken to the Lundberg, Dorr and Wilson cyanide plant at Terry, a smelter at Rapid City, and to Omaha, Nebraska. By 1908, only the high grade ore was being shipped out for custom milling, and that was to a smelter in Denver.[5]

By 1911, Portland had attained a position of considerable stature in the Bald Mountain district. In that year it was reorganized as the Trojan Mining Company, and purchased the American Eagle Mining Company along with the Bald Mountain mill. Later additions of the Two Johns (1917), Republic (leased 1917) and Ofer (1920) mining companies made the Trojan Mining Company's local dominance complete. Particularly substantial were the properties of the Ofer Mining Company. Consideration of the events leading up to Trojan's acquisition of Ofer gives a good indication of the extent of Trojan's dominance of the district.

Among the early large companies was the Imperial Gold Mining Company. Formed in 1890, it mined the Dividend, Burlington, Apex, Reindeer, Ophir, Rudolph, Dolphin, Costello, Baltimore and Chance claims. In 1902, it built a cyanidation mill in Deadwood capable of processing 100 tons of ore per day. Imperial gained a controlling interest in the Dakota Mining Company in 1907. The Dakota had been established in 1900 and worked properties including the Jack Pot and Gunnison mines and the Rehl, Lucy, Tiger, Mono, Peggy, Gunnison and Vulcan claims as well as operating cyanide mills in Deadwood and Central City. A series of accidents and the effects of a prolonged miners' strike in 1907 weakened the company and enabled Imperial to acquire it. The Ofer Mining Company was set up in 1916 and took over the Imperial later that year. In 1920 further expansion brought the Dakota, Imperial, and Reliance mines under Ofer management. That same year the Ofer and its new acquisitions were taken over by the Trojan Mining Company, which also included the holdings of the former Portland company.[6] Acquisition of the Ofer Mining Company was the final phase in Trojan's growing dominance of the district, but before 1920 the company had already acquired the Bald Mountain mill and made profound changes.

CHAPTER FOUR: BALD MOUNTAIN MILL - AN ECONOMIC HISTORY, 1906-59

The development of the Bald Mountain mill over a 53 year period was directly linked to the scale of operation and success of the three successive companies that controlled it. The ownership periods of the American Eagle (1906-10), Trojan (1910-28) and Bald Mountain (1928-59) Mining Companies create three periods for study. Other important events in the history of the mill include the beginning of large changes by Trojan (c 1913), the re-opening of and subsequent investment in the mill by the Bald Mountain Company (1934-9), and forced closure of the mill during World War II (1942-45).

THE AMERICAN EAGLE MINING COMPANY, 1906-1910

The very small amount of information which survives regarding the activities of the American Eagle Company comes from the Trojan Mining Company's records. The American Eagle Mining Company was incorporated on January 6, 1906 by a group of businessmen from Minneapolis and St Paul, with George Code appointed the first president. The company held twelve claims covering 167 acres at the head of False Bottom Creek and a small cyanide mill was constructed to process ores from the company's mines (their number remains unknown) and to take in custom work. In addition to the existing claims an ore body 14' wide was discovered during construction of the mill and an adit was driven into the hillside. The resulting Eagle Mine supplied the mill with ore from this adit entrance, immediately behind its main crude ore bins.[7]

The mill was constructed by J. E. Downs, and completed in 1908 after a delay caused by lumber shortages. During construction the company's mines had gone into production, so ore was sent to the Hildebrandt mill at nearby Blacktail. The mill was run as a 100-ton per day plant but was thought to be "capable of 300-tons per day" by Trojan manager H. S. Vincent.[8] That the mill was not developed to its full capacity may be due to the small scale of the Eagle operation. Although complete evidence is lacking, it is unlikely to have been a very large producer of ore. Far more probable is that the company relied upon custom milling for a significant part of its income. This aspect of the trade was very unreliable, particularly in an area well served with rail links and thick with competitors. Strikes in 1908 and 1909-10 closed down the vast majority of mining activity in the Bald Mountain area and had a disastrous effect on the smaller mining operations. It is quite probable that this situation weakened the Eagle Company, and made it ripe for takeover by the ever-growing Portland Company.

THE TROJAN MINING COMPANY, 1910-1928

The Trojan Mining Company was established in 1911 after the Portland Mining Company merged with the Clinton Mining Company under company president H. W. Seaman. The two organizations operated with joint management prior to this and had purchased the American Eagle Company and its mill during the fall of 1910. The new company held claims covering some 700 acres (Portland alone had over thirty claims). After consolidation of the various companies' interests, Trojan possessed assets of $5,114,117.66.[9]

Portland had first looked at Eagle's mill with a view to developing their own integrated ore processing facility. Transport of ores to custom millers such as the Lundberg, Dorr and Wilson Company and the American Smelting and Refining Company was a highly convenient solution which Portland had been further encouraged to use by the failure of small scale amalgamation and chlorination mill experiments at their Squaw Creek site. However rail costs were increasingly becoming a significant threat to profits and an "in-house" facility was an attractive alternative.

In 1911 P. H. Bertschy, a provider of large scale custom work for the mill and possibly a former client of the Eagle Company, suspended operations, causing production to slump to 100 tons per day.[10] A policy of increasing productivity at the company's own mines was pursued in order to remove the instability caused by the fortunes of such customers. By 1915 the Dakota, Portland and Empire mines (the company's major operations) were together producing 400 tons of ore per day while the mill was being adapted to this level of tonnage.

The custom ore problem was swiftly and successfully addressed. The first year of operation still saw the considerable sum of 11,688 tons being sent to custom mills while the Bald Mountain mill itself only processed 12,748 tons. However, by the end of 1912 the situation had been radically altered with 60,090 tons passing through the mill and only 227 tons sent for custom work. Soon custom shipments were almost totally eliminated apart from small amounts of specialized ores.[11]

Although custom ore exports were reduced, custom imports were accepted and reductions in rail freight charges encouraged the use of the mill as a custom facility. Ores were delivered to a shaft in the Portland mine and transported to the mill from there. Although there are few records as to the amount of custom ore taken in, earnings from this source were $2,624.86 in 1916 and $9,916.561 the following year.[12]

Vincent's intention to increase the mill's capacity was quickly put into effect and the mill was already surpassing the production of the Eagle period when it averaged 180 tons per day in 1912. It had reached about 300 tons per day by 1916. Plans were made in 1912-13 to upgrade the mill to 400 or even 500 tons per day. After significant modifications, 400 tons per day was achieved in 1917.[13]

In addition to increasing capacity, alterations were made to the mill so that it could retrieve gold and silver in larger amounts from finely crushed ore (slime) as well as more coarse material (sand). In 1912, 35,612 tons of sand were processed but only 24,915 tons of slime. The sliming operation developed quickly, and in 1915 slime was in the majority with 41,341 tons passing through the mill compared to 38,088 tons of sand. Further improvements in sliming facilities had brought the ratio to 55,709 tons of slime compared to a mere 32,220 of sand by 1922. The faster sliming process also increased the volume of material processed. From a total tonnage of 60,527 in 1912, production was to rise steadily until 1916 when 112,837 tons were milled. The 100,000 tons plus level was then maintained steadily for several years.[14]

During this period ore was supplied by Trojan mines such as Eagle, Empire, Portland and Decorah mine. A system of motor-wound cable hoists was constructed to pull the mine cars up and down surface underground inclines. Cars from the Empire mine descended a 1200-foot, 20% slope from the mine entrance by the Chicago and North Western Railroad while the Portland tunnel, which served a variety of Trojan properties in the Annie Creek area, discharged cars down a 2100-foot, 15% incline. Gasoline locomotives were used to bring the cars to the mill tramway which led directly to the mill's ore bins. A variety of ancillary facilities were constructed at the mill while the workers' town of Portland (renamed Trojan) received several new houses and a hotel was planned.

From 1916 to 1920 the Trojan Company expanded considerably. The Decorah and Republic mines were leased, then later purchased, and the Ofer Mining Company and the Two Johns mine were purchased as well. Ore from the Republic, situated in Blacktail Gulch, was brought to the railway in Deadwood Gulch by motor truck while Decorah was connected to the mill tramway system. Due to rich ore deposits, Trojan became the second largest producer in South Dakota during 1917, despite only being responsible for 6% of the total ore output. Gold production peaked in the following year with 23,850 ounces.[15]

While the efficiency of recovery was maintained, the expense of running the mill increased steadily. From an annual figure of $77,479 in 1914, the cost of operating the mill climbed to $107,447 in 1916 and $147,484 in 1918.[16] Although the mill was not forced to suspend operations during the First World War, a serious labor shortage ensued, pushing up costs both at mines and mill. Work was suspended in the Republic mine and although some custom ore was handled, tonnage at the mill declined by 5,748 tons in 1918. Despite the massive advances that had been made in the pre-war years at the mill, Trojan was unable to recover after the war. An inability to repay loans to the First National Banks of Lead and Deadwood led to the banks entering into part ownership of the company. By 1922 annual tonnage milled slumped to 87,929, and in 1924 the records declare "no tonnage mined or milled." The initial decision to suspend production in February 1923 was blamed on bad weather conditions and an announcement about re-opening in 1924 was expected but never came. Manager C. E. Dawson tried to raise funds to save the company but it finally went into receivership in 1926.[17]

There are insufficient surviving records to explain quite why the Trojan Company was unable to rescue itself from collapse but clearly government regulation of gold prices and the shortage of labor were both factors. As far as the mill is concerned, it is clear that despite the improvements it never operated at full capacity. An estimated yearly capacity of 182,500 tons in 1917 significantly exceeded the actual 112,837 tons in that peak year of milling. Despite these shortcomings, the Trojan Mining Company processed 1,144,000 tons of ore during its operating life, valued at $4,170,991. From 1918 to 1923 it was the second largest producer in the Black Hills. Perhaps the damaging losses came from the mines and only a brief period of working rich ores could offset them. By 1924, the Trojan Mining Company's assets had been stripped to $1,356,401 and a financial salvage operation was needed to bring mines and mill back into production.[18]

THE BALD MOUNTAIN MINING COMPANY, 1928-1959.

The Bald Mountain Mining Company was formed on November 1, 1928, and formally incorporated the following January. The property of the Trojan Mining Company was purchased for $87,946 and part of the holdings of the Mogul Mining Company were added. By the end of 1931 assets stood at $5,004,680.89, and property totaled about 3,000 acres. President Seaman was replaced by O. D. Collis from the company's Clinton, Iowa head office.[19]

Apart from some development work, notably at Two Johns mine, the new owners remained largely inactive at first, employing only 30 men as a maintenance crew. An ill-timed start to milling operations in November and December 1930 foundered due to lack of financing, and work was suspended until the price of gold rose from $20.67 to be fixed at $35.00 per ounce on January 31, 1934. The first mine to go back into production was the Portland followed by the Eagle. Other mines made small contributions but many were slow to return to full production (neither Clinton or Mark Twain began work until 1937). The Portland, Clinton, Dakota, Empire and Two Johns mines were the main suppliers of ore to the mill during the pre World War II period but a host of smaller operations were also working, including the Ajax, Alaska, Trojan, Mogul, Mark Twain, May Queen and Foley mines.[20]

Investment at the mill immediately before World War II was considerable. Major changes were made in the ore crushing and milling facilities, and the plant was turned over to all-slime processing. In 1939 a whole new sub-section of the mill was added to undertake the preparation and roasting of unoxidized, or blue, ores, mainly from the Two Johns mine (but also from Clinton, Portland, Empire and Juno). A pilot test roaster was used for two years and a full scale roaster built 1939, beginning production on June 1st at a rate of 93 ½ tons per day. The mill ran three shifts, each staffed by a crusher operator, mill man, and solution man. Also employed were a superintendent, foreman, repairman and assistant, an oiler, sample house operator, assayer (on the day shift only) and two night watchmen. Investment in the mines and mill paid off as production rose at a steady pace from a 1935 total of 86,760 tons of ore milled to 119,510 tons in 1937, 122,524 tons in 1939 and a peak of 134,985 tons for the year 1941. During the same period, however, the cost of running the mill rose in equally dramatic form, from $113,985.07 in 1935 to $193,633.85 in 1941.[21]

Perhaps the two key factors in the maintenance of profits during this period were the production of high value ores from the mines and the availability of cheap labor with which to do it. As early as 1937, manager C. E. Dawson commented that "we have practically reached the limit of further extension of the ore bodies in the Portland mine." The significance of this remark lies in the fact that Portland had produced 82,421 tons of ore that year, over 50% of the company's total output. Dawson predicted a drop in production "before long" and was proved correct by the Portland's fall to 24% of the total by 1940 and 19% the following year. The pumping out of Two Johns mine and its return to service, supplying high value ores to the new roasting facilities, was an important step in off-setting losses. The Bald Mountain Mining Co. was able to maintain an increase in profits despite the additional problem of the exhaustion of high grade deposits at Clinton mine in 1940. By 1941, Two Johns was supplying 25% of the company's output. Company president Collis had himself "anticipated lower amounts of gold... [in 1941, but] ...high grade pockets of ore helped to make up the total figure." It is also worth noting that a long fought battle with the state of South Dakota to have the company's taxes reduced had resulted in partial victory in this year, further improving results.[22]

The internal problems of the Bald Mountain Company were overshadowed by War Production Board Order L-208 which compelled the closure of gold mines for the duration of World War II to conserve resources and release labor for other work. The order was issued on October 8, 1942, but the Bald Mountain Company was allowed to continue small scale production for six months from December 7th of that year. That time was taken by the processing of ore, already broken in the mines, at a rate of 125 tons per day. Final closure was on May 25, 1943. Despite many years of litigation, compensation was not forthcoming from the government and the company weathered the war time period while a six man maintenance crew attempted to limit deterioration.[23]

Even during the war it was understood that a post-war labor shortage was inevitable. Collis wrote in 1943 that "we [the board of directors] are in hopes that when the war is over many of our former employees will return to us," but he was to be disappointed.[24] The war resulted in a severe drain of skilled mining labor from the Black Hills. Many miners and some of the company's key personnel who moved into other branches of the mineral industries during wartime did not return.

Work recommenced on July 1, 1945 with the Portland, Clinton and Dakota mines re-opening first. Small contributions from Foley and Mogul mines followed and the Decorah was brought back into production in 1953. Open cut mining was developed on a small scale and a scattering of pits supplied ore during summer operating seasons from 1948-59. Some custom ore was also taken in from outside mines such as the Astoria and Gold Bug. Two Johns remained closed as roasting had become uneconomical. The mill began work at 100 tons per day but was processing 322 tons per day in 1949. A peak of production was reached in 1952 with a 370 tons per day rate established.[25] Throughout this period virtually no structural alteration of the mill took place. It is likely that the company did not consider the expense warranted in light of the declining ore values.

The company's reliance on cheap labor during the pre-war years had discouraged it from mechanizing mine work. After the war this dependance exacerbated the labor shortage problem and machines were hastily employed wherever possible. Workers were still hard to get, resulting in escalating wages in competition with the Homestake mine. The turnover of labor was exceedingly fast, in fact 100% in 1946, but the company was able to maintain its work force at an average of 118 per month, a huge improvement on the 83 that had been secured the year before. Mechanization and more efficient mining techniques had enabled the company to reduce labor requirements by 30% from pre-war levels, but this reduction proved to be insufficient as costs rose in the 1950s.[26]

Little more than a year after operations had recommenced Collis wrote gloomily of how "there is a feeling among the executives that the life of the Bald Mountain Mining Company is very limited. In fact we should not consider its life excepting from year to year." Expenses rose, especially underground, to problematic levels. "The mining expense is climbing considerably and there does not seem to be anything we can do about it," Collis wrote in 1946. The cost per ton of ore milled in 1946 stood at $5.07. The lowest during the company's operation had been $3.47 in 1942 and the previous highest $4.41.[27]

This situation was to worsen in the next decade and the final working mines (Portland, Clinton and Dakota) closed on July 25, 1959. The mill had been operating minimum hours on a skeleton staff through the winter of 1958-9 and milling operations finally stopped on July 31, 1959.[28]

CHAPTER FIVE: THE DEVELOPMENT OF GOLD MILLING TECHNOLOGY

In tracing the line of development from early gold milling techniques used in the Black Hills through the technology applied at the Bald Mountain mill, several trends emerge. As the most accessible and profitable ores were worked out, fresh deposits were exploited. Each variety of ore required solutions to new problems and spawned successive generations of technological change. These generations of technology provided continuity between the phases of the Bald Mountain mill. During the short history of gold milling in the Black Hills, the rate of this technological change has been remarkably swift, perhaps due to the pace of operation and intensity of exploitation that characterizes gold fields. In addition, the majority of techniques and machines have arrived, at least partly developed, from other gold fields and then been adapted to local conditions.

The earliest gold deposits recovered were of the "placer" type - gold eroded from ores close to the surface and found in river bed gravel. The heavier metallic content of this gravel was recovered by panning. Several preparation methods were used, often essentially consisting of using shallow troughs with transverse ridges in the bottom to catch the heavier gold. This basic principle proved to be remarkably enduring. Inclined tables covered in coarse corduroy were still used in conjunction with more sophisticated techniques in major mines of the 1920s.[29] Such devices could use mercury amalgamation to catch the finest gold dust. In this process mercury dissolves gold and silver to retain them in a solid, amalgamated mass. Mercury placed in the bottom of the troughs would retain exposed gold which flowed or landed on it.

As "free milling" ores (those requiring relatively simple milling techniques to release the gold and silver) gained prominence over placer as the main type of deposits being worked, mercury amalgamation was also used in mills. To enable the mercury to amalgamate ore was crushed to expose the metal content and then passed over copper plates coated with mercury. A later development was the amalgamation pan, where ore, in slurry form, flowed through large mercury coated pans while being mixed with the mercury by rotating blades. The resulting amalgam collected at the bottom of the pans to be removed later. The bullion was then extracted by distillation or filtration.

To crush ore many early mills used an arrastra, a large circular stone running around inside a cobbled trough. This method was eventually superseded by stamps. The stamp consisted of a hammer head fitted to a vertical shaft that fell on ore placed in a mortar beneath. Stamps were frequently arranged in large "batteries." Arrastras and stamps could both be used to combine the crushing and amalgamation processes by working the ore wet with mercury. A typical stamp mill of the 1880s shows several similarities with the earliest phases of the Bald

Mountain mill. Mine cars deposited crude (unprocessed) ore into large bins. From here it was fed to primary crushers designed for the heavy work of breaking the large pieces of ore. This crushing was done with the ore still dry. From the crushers the ore moved to the stamp batteries, sometimes with mercury added to the mortars, though possibly just with water. After stamping the ore passed over the amalgamation plates where the amalgam was collected. The bullion (gold and silver mixed) was recovered by heating the amalgam beyond the boiling point of mercury in sealed retorts. The vaporized mercury was drawn off and condensed in a water bath for reuse while the bullion was refined.

The mercury amalgamation method, however, was unable to recover bullion from the refractory ores that contained gold and silver in complex physical and chemical bonds, requiring more sophisticated techniques to release them. As the free milling ores found closer to the surface began to be exhausted, new technology was required to process refractory ores.

One solution to the problem of milling refractory ores was the chlorination process. The chlorine process was invented in 1848 by C. F. Plattner in Germany. Finely crushed ore was mixed with chlorine and sulfuric acid diluted in water and placed in chlorination barrels. Chlorine gas was produced and gold was dissolved. The solution was then drawn from the bottom of the barrels and pumped to precipitation tanks. In these tanks a ferrous sulphate was added to precipitate the gold from the solution. Alternately, other metallic sulphides, hydrogen sulphide gas or charcoal could be used. The resulting gold precipitate was separated from the chlorine solution and placed in filters, where it was pressed between the leaves of filter bags until fluids passed through and solids were deposited on the bags. The filter presses were periodically cleaned and the precipitate dried and roasted with fluxes to remove slag and release the bullion.

In order for chlorination to work effectively, ores had to be finely crushed by a secondary crushing facility, duplicating the role of stamps at an amalgamation mill. Although stamps themselves were still used, new types of rotary mills were increasingly employed for finer grinding. In the case of refractory ores like those found in the Black Hills, heating in rotary roasters was often required to weaken the physical bonds of the metal and rock before the application of chlorine.

Although the chlorination process was successfully used on the refractory ores of the Black Hills, one major disadvantage of the process was that it could not recover the silver contained in these ores. Moreover, the chlorination process was always expensive and the advent of cyanidation quickly caused its demise. Cyanidation proved to be a more enduring method of processing Bald Mountain refractory ores. It is important to note, however, that in the chlorination mill the basic sub-divisions of process that characterize the cyanide mill can be seen: coarse crushing, milling (fine grinding), chemical action in tanks and precipitation/ filtering.[30]

The cyanidation process was developed in 1887 at Glasgow University, Scotland, although the principle had been outlined as early as 1846. Potassium cyanide was originally used but sodium cyanide, a cheaper alternative, became standard. In dilute form cyanide will dissolve gold and silver from their ores and carry them in a solution from which they can be precipitated. The original patent also included the use of zinc as an agent in precipitation as zinc attracts the sodium in the solution, allowing the metals to be released, collected and smelted for bullion. Aluminum dust, charcoal and electrolytic action were used as alternative precipitation agents. The success of cyanide's dissolving action can be influenced by the acidity of the pulp (crushed ore and cyanide solution). Several additives could be used to control this factor - crushed lime was applied at Bald Mountain.[31]

This process was first practiced commercially in New Zealand (1889) and reached the United States with the Consolidated Mercury plant in Utah (1891). Cyanidation was an immediate success in many areas, though in the Black Hills adaptation to localized conditions at first reduced the effectiveness of the process. The Homestake mine, in Lead, South Dakota, was the first to bring the technique to the Black Hills in 1900. Cyanide was initially used as a leaching agent. Dilute cyanide was added to large tanks of crushed ore, passing through the solid material and dissolving the metallic content into a solution which could be collected, filtered and finally precipitated to recover the bullion. In this form cyanidation had much in common with the chlorine process. To be useful for leaching, ore had to be milled to sand size (approximately smaller than 0.00714") and more effective ball, rod and roller mills were increasingly used in place of stamps for the fine crushing process. Cyanide was added at the milling stage, in a similar way to wet stamping with mercury. Each sand tank received several washes of cyanide. The solution was drained from each wash, filtered to remove any solids and the bullion removed by precipitation.[32]

From the first application of the process it had been clear that improved dissolution could be gained by treating ore crushed to slime consistency, (smaller than 0.0025"), and that some ores required this level of crushing to enable cyanide to dissolve their metals. To make this method economical proved to be a difficult process and many mills adopted sliming technology slowly, not having the finances to risk an all-sliming operation with low-value ores.

In mills both partially and fully practicing slime treatment, it was necessary to develop various types of classifiers to separate slime and sand. J.V.N. Dorr's rake classifier was developed in the Black Hills in 1904. It separated the two constituents by their relative rates of settling. When mills turned to all-sliming production, the sand discharge end of their classifiers could be connected in closed circuit with the fine grinding equipment (usually a rod or ball mill) in order to contain the sand until it had been ground to slime. The use of ores processed to slime grade was increasingly common with the use of improved milling technology, often in closed classifying circuits to trap the ore and ensure fine grinding, or with a secondary stage of coarse crushing added. By 1936, sand leaching was "seldom incorporated in new plants."[33]

For the cyanide's dissolving action to work effectively, oxygen is needed within the mixture and the solids have to be kept suspended in the dilute cyanide. By agitating the mixture both needs can be met. Early agitators used mechanical action with compressed air applied later. In 1907, Dorr combined the two in his design. Another problem was to separate the gold and silver bearing liquid from the solids. Dorr's thickener of 1905 enabled solids to settle and be removed by a drain while liquid was drawn off. By arranging thickeners in sequence, solids could be moved to each successive tank, releasing their bullion content to solution as they proceeded.

The counter-current method was a variation of this system that was in common use by the 1920s.[34] The bulk of the solution in the thickeners did not flow in the same direction as the thickened solids, following them from tank to tank, but moved in the opposite direction. This arrangement meant that a solution with a low concentration of metal, or completely free of it (barren) would become gradually enriched as it moved through the successive thickeners. The solid would be in contact with the liquid when the former was at its strongest bullion concentration and the latter its weakest (hence, most chemically active). Before bullion was precipitated from the pregnant solution, filtration was used to remove suspended solids. Early filters using a compressing action were superseded by those using a vacuum to remove the gold and silver solution from the solids. Rotating filters were followed by the highly successful vacuum leaf filter (known as the clarifier) invented by Moore and Butters in 1903.

Despite the use of occasional alternatives zinc remained the most effective agent of precipitation. The zinc box, an early method of precipitating bullion by bringing solution into contact with zinc shavings was, Dorr claimed, adopted partly to avoid the patent specification of zinc dust as the precipitant.[35] A more effective system of precipitation was to feed zinc dust directly into the solution.

It was discovered that precipitation would be more effective if the oxygen that had been introduced to aid the dissolution of metals during agitation was removed. A process developed by T. B. Crowe around 1907 passed the solution through a vacuum chamber to remove the majority of the air. Zinc dust was then added to the de-oxygenized liquid. In the commonly used Merrill process, dust was added to only a small part of the solution which was then returned to the main flow of liquid. The precipitate was collected in either filter presses or in filter bags, suspended in the solution. It was cleaned from these and taken to be dried and melted to release the bullion.

Throughout the development of gold milling techniques, certain similarities of function persist and are found in each successive generation of technology. In terms of coarse crushing of the ore, a continuity can clearly be seen in the amalgamation, chlorination and cyanidation techniques. In all three coarse crushing exposes the metallic content of the ore to prepare it for the chemical action, but in the amalgamation and cyanidation processes this chemical action also takes place during the wet milling stage.

There is also a link between plate amalgamation, barrel chlorination and cyanide sand tank leaching. In all three bullion and a chemical agent are brought together and bond without mechanical action to yield a combination of the two. Although the precipitation stage only dates from chlorination technology, it was continued and developed in cyanidation. The final production of bullion by forms of smelting is common to all types of mill-based gold operation.

Bearing in mind this smooth flow of progress, it is important to note that cyanidation marks a stage of increasing complexity in gold milling. Although the basic production stages were maintained, an important degree of sub-division took place during the process' first few decades. Coarse crushing became divided into primary and secondary; the non-milling chemical stage was broken into thickening, agitation and secondary thickening, and the precipitation stage saw the addition of the Crowe vacuum process. However, the cyanidation technique cannot be seen as separate from its predecessors. Links between techniques were not only historical: in many cases cyanide mills processed ores with a significant amount of coarse gold content and incorporated a mercury amalgamation facility into the production process.[36] At the Bald Mountain mill a similar overlap in generations of technology can be seen between the sand leaching and slime decantation systems.

This underlying continuity of process means that the growth of the Bald Mountain mill occurred by altering or extending existing production areas rather than adding completely new ones. Consequently the mill has undergone mainly lateral expansion of the structure to accommodate increased output, rather than linear expansion along the flow of production. The machinery used has also followed the three primary phases of cyanide technology development: sand leaching, mixed practice and all-sliming. The latter was refined to a counter-current decantation system.

CHAPTER SIX: BALD MOUNTAIN MILL: A TECHNICAL HISTORY, 1906-59

Bald Mountain mill was built into a natural hillside and utilized gravity to aid the flow of materials through the building. Its siting allowed construction of a leveled area above and behind the mill to accommodate mine car tracks and attendant buildings. Cut into the hillside below part of these tracks were the crude ore bins and primary coarse crusher facilities. A belt conveyor covered the short distance to the main mill building which was set on a lower level than the base of the ore bins.

The mill itself was constructed with four terraced levels that essentially remained the core of the plant throughout its operative life. The uppermost level supported the main crushed ore bin, and later storage tanks. This level was the only one to undergo appreciable linear extension (on a north-south orientation) by being built further back into the hillside to create later sub-levels. These sub-levels initially accommodated the ore sampling facilities and over the mill's history were enlarged to include dust collecting, secondary coarse crushing, and part of an unoxidized (blue) ore treatment circuit.

The second distinct level has retained a strong degree of integrity as the milling and classification level. It also included primary thickeners when extended laterally (to the west). The third level originated as the sand tank floor, but later accommodated thickeners and was also extended laterally (to the west) where it partly encroached on the level above. The lowest level featured a raised floor above the mill sumps and air compressors, though the floor itself accommodated pregnant solution tanks, agitators and the precipitation stage.

The basic four levels were a good deal less inviolate than the above summary depicts. However, it is valuable to use them as a starting point for viewing the mill's growth. Additions at the mill were often quite piecemeal. A one-story, sloping roofed shed built onto a previously external wall was a common method of extension. Foundations and retaining walls were either of rough-hewn stone or poured concrete, and the structure was wooden, with some exceptions. Roof and wall coverings were fashioned from wooden boards, roofing felt, rubber and metal sheet.

Periods of financial investment and mine acquisition, particularly changes in ownership, had profound effects on the mill. The history of the mill can be divided into three phases representing three different owners: American Eagle Company (1906-10), Trojan Mining Company (1910-28) and Bald Mountain Mining Company (1928-59). Each phase is described in a fashion that follows the flow of ore through the mill for easier comparison of operation and plant. Ancillary buildings have been given a separate heading within each phase.

THE AMERICAN EAGLE COMPANY MINING, 1906-10

Information about machinery and practice at the American Eagle mill is somewhat scarce. It has been necessary to rely on early documentation from the Trojan Mining Company's ownership period, as well as photographs and field work. In its original phase this Bald Mountain mill was a small cyanide leaching plant. The cyanide leaching process was a relatively simple one and the subdivisions of that process within the plant were clearly defined by the four levels.

The main crude ore bin was built into the hillside, with the wooden bin structure set against concrete retaining walls. A proposal drawing shows vertical walls dividing two new bins and a front wall, with four windows, enclosing the front (the pitched roof house had been removed), but it is likely that no alterations were carried out until the Trojan Mining Company took over in 1910 and the capacity of the mill was increased. In an early photograph of the bin, the concrete wall is complete and the framework and sloping sides of only one bin can be seen. It is the central of the three proposed, set furthest back into the hillside and directly behind the crusher house, a small pitched roofed structure. It is possible that the additional bins were constructed at some point in the Eagle phase to form a trio set around a central crusher house.[37]

The bins were emptied by manually operated gates where ore fell through or over grizzlies (iron grills) into or past the crusher beneath. If the ore was small enough to pass through the grizzly bars it fell directly down sloping wood walls to the bottom of the bin. Material that could not pass through the bars was diverted by them into the primary coarse crusher, the largest pieces possibly being broken by workers with sledgehammers. The crusher was a heavy-duty machine designed for breaking up large pieces of rock, although its exact type is unknown. It was powered by an electric motor running on 440 volts, as were all machines in the mill.[38]

Beneath the primary coarse crusher was the base of a 16 inch-wide inclined belt conveyor that received both the crushed and suitably small ore. Concrete retaining walls that stood parallel to the belt at its base still survive. The conveyor led to the main mill building over a distance of 117 feet and an elevation of approximately 30 feet.[39] Over this distance it was enclosed in a weather boarded housing with a shallow pitched roof and pairs of small windows. The conveyor housing was supported on four wood trestles of increasing height.

At the top of the conveyor, ore was deposited into an ore bin with a 365-ton capacity. The ore bin was built of wood with heavy exterior timbers providing additional support on the lower section and an upper floor housing the head of the conveyor and providing room for maintenance and observation. The outer wall was extended on the east side to enclose the three flights of stairs to the upper floor, and windows were placed on east, west and north sides.

Ore was discharged from the north side of the 365-ton ore bin by two "Challenge" feeders, known to have still been present in 1912. These feeders consisted of a large hopper from which ore could flow onto a revolving disc, driven by a bevel gear from beneath. As the disc moved a specified amount of ore could pass between a pair of adjustable metal wings. In the Eagle mill the timber cube framework of each feeder would have been positioned above and behind the chilian grinding mills they fed. The chilian mills were manufactured by the Monadnock Company and had seven-foot diameter bowls and nine-foot diameter flywheels. The ore was ground to a fine consistency by the action of rollers, driven from a central shaft, crushing against a ring in the base of the bowl. The bowls had outside diameters of 84 inches and the rings had an internal diameter of 46 ½ inches. The bottom of the mill pans sloped downwards to the discharge side of the mill in order to use gravity flow. The two mills worked as independent primary grinding mills, receiving and discharging ore separately and without passing it on to secondary grinding.[40]

The retaining wall at the lower extent of the ore bin level was constructed of stone with a concrete sill (possibly a later addition). Angled slots, a feature not found in later phases of operation, are present which could have corresponded to the line of descent between the bin and the former site of the primary (chilian) mills. Power was transmitted from an overhead line shaft arrangement which was used "as we inherited it" by Trojan in 1913.[41]

A single, unspecific reference to "rolls" and a "classifier" requires mention here.[42] "Rolls" would seem to imply that a secondary fine grinding system, composed of roller mills, was in place when the Trojan Company took over the mill. Their exact place in the production flow is unknown, and it is even possible that they were superseded by the chilian primary mills and merely left in the mill. Although the Eagle Company was not dividing its pulp into sand and slime fractions, a classifier could have been used to return coarse material to the mills for further grinding. There was no other method of grading sands present at this stage so a classifier could have been placed after the chilian mills. No other reference to this machine has been found and its type is unknown.

At the eastern side of the primary mills stood a mill solution storage tank. From here cyanide was introduced to the ore in the mills, making it into pulp. The crushed ore was transferred from the primary mills by launders to six sand leaching tanks, twenty-eight feet in diameter and eight feet deep, situated on a lower level of the mill. (This proposed arrangement assumes the absence of secondary fine grinding and classification).[43] Cyanide solution was also channeled down to this level in pipes from the mill solution tank. The bottoms of the sand tanks were fitted with metal grates overlaid with a filtering screen, usually of canvas, through which the gold and silver bearing solution could pass. Solids were periodically cleared through a discharge gate in the bottom of the tank. At Bald Mountain this was probably done by hand, though expensive mechanical excavators were used in large mills and sluicing was practiced in areas with a more plentiful water supply.

Ideally ore would be crushed to a consistency that would allow percolation of each cyanide wash at a rate of one to three inches per hour. A common number of washes was four: one of strong cyanide, two of weak cyanide and one of water. Each leach would have taken about fifteen hours to complete and the water wash about twenty hours. Combined with charging and discharging the whole process took from five to ten days. Two methods of adding the solution were commonly used. Liquid could either be poured in from the top of the tanks or could be pumped in from the bottom until the tank was full, and then allowed to drain out. The latter method agitated the ore pulp and improved dissolution of the metals. The exact nature of the operation at Bald Mountain is unknown, although the arrangement of the sand tanks below the mills implies the use of a gravity aided top pouring method.[44]

At the sand tank level, the building extended latterly from the main structure to accommodate the tanks. The main slope of the roof continued in the central four ranges of the level. The pairs of four bays placed at either side (accommodating two tanks each) were built lower with pitched roofs and small windows punctuating them at two levels. The level below the sand tanks was constructed with a stone retaining wall. Stone foundations were added for the support of gold and silver bearing solution tanks ("gold tanks"). Two wood gold tanks (12 feet deep and 14 feet in diameter) remain on-site, and stone foundations are found underneath the Trojan period agitators that have been capped with concrete. It is possible that these are the sites of other Eagle gold tanks. How the mill's sand leaching operation continued if these are gold tanks that were removed is unclear, since the number of sand tanks was not correspondingly reduced. Possibly less washes were used (and therefore less solution drained off) after the application of finer grinding when sliming was introduced and the gold tanks were no longer required.

Beyond the gold tanks the precipitation level continued. A raised wood floor was constructed to compensate for the ground level falling away below the tanks. Details of the precipitation stage at the Eagle mill are sketchy. "Burt" filter presses were used to remove solids from the bullion bearing solution. An unknown number of these devices probably operated by mechanically pressing solution between the leaves of a series of filter bags. The fluid would pass through and drain away while the solids remained on the leaves. As far as is known, no other filtration method was used and there was no vacuum system for removing oxygen from the solution. Although one is not known to have existed in this period, a tank of hydrochloric acid was the preferred method for cleaning the filter leaves, "every week or two."[45]

After filtration, the solution moved to the zinc precipitation stage. Information from 1912 indicates that the Trojan company inherited a Johnson zinc lathe. Such a machine would have been used to manufacture zinc shavings, suggesting that zinc boxes were used by the Eagle company.[46] The zinc box was an elongated trough divided into a series of compartments, each with a mesh bottom supporting a layer of zinc shavings. Gold and silver bearing solution was fed into the first compartment, and as each compartment filled, it would fill the next by rising through the mesh. In this way the solution was brought into contact with the zinc. A drain beneath the box took away the solution and the water from a subsequent zinc washing stage. Zinc compounds from the first box were then taken for refining while the ones below (having precipitated less gold and silver) were moved up one compartment each.

Barren solution leaving the zinc boxes flowed to sump tanks constructed under the raised floor, at natural ground level. The earliest Trojan drawing of the mill shows a pair of large circular sump tanks. If these both date from Eagle Company operations, they would have served to receive barren solution which probably had cyanide added (to make mill solution) before being pumped back up to the mill solution tank. A second storage tank, sited near the first on the western side of the primary mills, is listed as a "barren solution tank" in 1916, but may have served Eagle as a mill solution storage facility. A single story, sloping roofed "clean up room" was built onto the north side of the lowest floor of the mill. This facility was used to clean the filter leaves which would periodically become clogged with lime.[47]

No details are known of the equipment used in the refinery during this time. Most likely an oven for drying the precipitate would have been present as well as a furnace for melting it, after fluxes had been added to separate any slags (impurities). Refinery furnaces were generally of the reverberatory type, so that the graphite crucible full of precipitate would be heated without direct contact with flame.[48] In the early Trojan period inquiries were made about converting the furnace to oil firing. This implies that the Eagle Company had been using either solid fuel or gas firing.

Several buildings were constructed outside the main mill complex during the Eagle phase in order to supply essential services to both mine and mill. A single story warehouse was built, to the east of the mill, beside the road to the railroad and to Portland (later Trojan). The mill proper was served by three ancillary buildings. A small electrical substation was located close to the mill on its east side, about half way down the hillside. This substation converted main current from the public supply used by the mill. A small, wood single story assay office, for the testing of ore samples, was constructed on the sand tank level, to the east of the mill. Also on the east side of the precipitation level was the refinery, a small, wood pitched roofed structure with a short steel furnace chimney.[49]

THE TROJAN MINING COMPANY, 1910-28

The major change at the mill during the ownership of the Trojan Mining Company was the gradual introduction of sliming technology. This new technology brought alterations to the fine grinding stage and additions to the sand tank and precipitation levels. In terms of the overall development of gold milling technology, the mill at this phase stands between the early all-sand leaching and later all-sliming systems.

Phase One, 1910-16

By 1912 there were three crude ore bins at the top of the mill in order to increase capacity. The two additions were in front of the original and divided by a pair of sloping walls, in the form of a pitched roof. Although it is possible that the two additional bins had been built before the Trojan Company took over, an increase of capacity to 1000 tons in 1914 would correspond to changes during the early Trojan period. The primary coarse crusher was situated between and beneath the bins, which had small windows added for illumination. The primary coarse crusher was a Gates Number 5 "K style" gyratory machine belt driven by a 35 HP motor running at a speed of 850 RPM. The motor was situated in a chamber in the concrete base of the ore bins and placed above the crusher. A gyratory crusher operated by the rotation of an internal grinding cone revolving about an eccentric axis. Rock was caught between the cone and the inner wall of the crusher. This gap could be set to grind to a specified grade, in this case 1 3/8 inches. A belt drive from the crusher flywheel transmitted motion to a bevel gear system powering the main conveyor to the mill and a pan feeder, an 18-inch-wide belt conveyor acting to carry material between the crusher discharge and the main conveyor.[50]

To take selected ore samples for assaying from the 365-ton crushed ore bin, a sampling system was constructed in 1912. This system was housed within a sloping roofed structure built against the uphill (south) side of the ore bin. A bucket-like device at the top of the main conveyor from the crude ore bins was used to divert a given amount of ore to a sampling bin, created by a diagonal division of a fraction of the 365-ton bin. The sample bin was in three parts which could be released independently to the sample room below where a vibrating screen retained the larger pieces for inspection. To return the unwanted sample material to the ore bin, a bucket elevator was situated beneath the sample room floor which rose to deposit ore, through a chute, into the 365-ton bin.

On the fine grinding floor, the chilian mills were retained as primary milling devices, though there seems to have been attempts to improve the machinery as the mill moved toward part-sliming. In November 1910, shortly after the mill came under Trojan ownership, manager H.S. Vincent proposed the mill "capable" of using two "Eclipse" roller mills and "2-7 Trent mills". Vincent seems to have been thinking in terms of a two stage fine grinding system to bring ore to the required slime grade with the Trent mills grinding ore wet (with the addition of cyanide) and the rollers grinding dry.[51]

There is no evidence that this proposal was ever carried out, though a reference to "mill no. 3" in September 1912 seems to have been a record of a brief experiment with alternative milling devices. An illustration of approximately the same period shows what appears to be a solitary roller mill positioned on a platform at the north side of the 365-ton crushed ore bin. In addition, proposals for a pair of ball mill/classifier circuits were made as early as 1916, but never realized.[52]

In order to sort the sand from slime a pair of classifiers was installed around 1913. They were positioned on a timber platform raised above the milling floor and projecting northwards over the third (from east to west) sand tank on the level below.

Although this floor has long been removed, a flight of stairs can still be seen rising approximately half the height of the building which may have been a point of access to this upper level. Crushed ore was transported from the chilian mills up 40 feet to the classifiers' platform by a pair of vertical bucket elevators. Each classifier operated as primary classification units working and discharging separately without being in series to another classifier.[53]

The Dorr rake type classifiers used consisted of a pair of reciprocating moving rakes set in an inclined trough filled with solution and operating at approximately five rakes per minute. The reciprocating motion was supplied by connecting rods and eccentric cams situated above the rakes in order to keep them clear of the liquid. The rakes pulled pulp up the trough but on the return stroke they lifted clear of the bottom of the trough, allowing fine slimes to flow free and leave the lower end of the trough with the overflow fluid. Since there was no facility to return material for further milling once it had entered the classifiers at the Bald Mountain mill, it can be assumed that some form of screen was used on the mills to stop excessively large pieces of ore being discharged to classification. The classifiers were driven by electric motors via belt or chain, though details about these motors are unknown. Individual motors, parallel to the classifiers' drives, are likely to have been used through an overhead line shaft arrangement. Working from a shared motor would also be possible. The classifiers seem to have been installed before any of the other technology required for the treatment of slimes. This change implies that the partial conversion of the mill was undertaken at a slow pace and perhaps that it was undesirable to close the mill down completely while refitting took place.[54]

An overhead crane, spanning the width of the fine grinding level, was installed in 1916 to enable the movement of machinery for repair. It was designed to bear six tons and ran on rails resting on beams upon rows of timber pillars erected inside the existing walls of the building. Additional trusses were added to strengthen the rail support in 1917. On the level below the chilian mills the sand leaching tank arrangement was maintained intact and continued to operate. Sands were discharged from the classifiers and flowed down to be distributed into the tanks. The slime output from the classifiers passed into pipes or open launders to the primary thickeners. This action would probably not have required the application of pumps due to the roughly four foot drop to the thickeners.[55]

The processing of slimes began in earnest around 1914 with the installation of a thickener 40 feet in diameter and 14 feet deep, constructed from timber staves bound in steel tie hoops.[56] The Dorr thickener allowed solids to settle out from the pulp and be removed while the solution containing gold and silver remained at the top of the tank and flowed away. A central shaft driven from above the tank turned radial arms at the bottom, clearing settled solids away through a central drain. Pulp was fed into the thickener tank by a launder passing over the surface to the center, while the level was kept constant by a discharge launder. Having separated from much of the solid pulp, the "clear" solution left via the discharge launder.

Primary thickener number one was constructed on timber cross beams set on concrete piers. These were sited on the milling level, at the western side of the chilian mills, and raised the tank considerably above the floor level. This level of the mill was extended both to the west and south, uphill below the west side of the 365-ton crushed ore bin level. To create space on the milling floor, the barren solution sump that stood to the western side of the primary (chilian) mills was moved up to an extension of the 365-ton crushed ore bin level above it.[57] The mill solution tank at the opposite end of the milling floor was also moved to the east of the 365-ton bin. In this way the top level of the mill building was expanded laterally, continuing the pitched roof line from the 365-ton crushed ore bin to house the mill and barren solution tanks.

The clear solution overflow from primary thickener number one was either returned to the primary mills to aid the cyanidation and become further enriched or flowed downhill to the main mill solution sump. At this early stage, the mill's precipitation department did not have the capacity to handle the extra solution directly. The pulp leaving the bottom of the thickener (the "underflow") ran by gravity through a pipe to three 16 foot deep agitators which were installed between 1912-16. These 17 foot diameter timber tanks were sited along the tier below the sand tanks where the gold solution tanks stood.

The agitators were round, flat bottomed tanks constructed of redwood staves bound by steel bands. Slime was fed in from the top of the tank and any solids would settle on the bottom. Here they were scraped towards a centrally positioned shaft by two rotating arms, each with a series of ploughs, that were attached to the same shaft. Each shaft was driven by a belt from overhead line shafting via bevel gearing. Compressed air was introduced, forcing solids up the inside of the shaft to a pair of revolving launders at the top of the tank, where they were distributed back into the tank. A launder at the top of each agitator took the solution, including suspended solids, to the next so that the agitation process continued through all three tanks, running west to east. Two existing gold tanks were retained for receiving the pregnant solution from the sand tanks. It is uncertain what happened to the solution from the agitator series after it had left the final tank. It is unlikely that this extra volume was being put through precipitation at this stage as only three zinc boxes were in operation in 1912.

In place of the earlier filter press a Butters' vacuum filter was in operation in 1914. A series of filter bags stretched around perforated metal tubes were placed in an elongated trough filled with pulp. A vacuum in the tubes would suck any solution present in the pulp through the bags and away through pipes connecting the tubes. After this operation a wash of water was used to clear the bags of barren pulp which was then flushed away as tailings. Filtered solution was passed to the gold tanks by vacuum pump of 14 inch bore and 12 inch stroke.[58]

The position of the Butters' filter is unknown, but it is likely that it survived to be recorded on a plan of 1916 which shows two bays having been added to the north side the mill building to accommodate a 11 feet wide, 29 feet long filter. By 1925 a vacuum pump of 14 inch bore and 12 inch stroke was added.

These two bays also housed an air compressor engine on the ground floor below. This compressor would have been installed around 1913 in order to provide air to the agitators. It was built by Ingersoll-Rand and run by a 40 HP electric motor. An air receiver tank, 3 feet in diameter and 18 feet long, was placed against the north wall of the mill next to the compressor/filter housing to maintain pressure in the agitator supply system.[59]

The Butters' filter does not seem to have sent agitator solution to the zinc boxes, but instead deposited it in the mill solution sump. The mill solution and barren solution sumps located beneath the floor of the filtration and precipitation level were 26 feet in diameter, 7 feet deep and illustrated as being circular, possibly of wood construction, as were many liquid storage tanks in the mill.[60]

In an attempt to stop the leaching of pollutants into False Bottom Creek, from the tailings dumped on flat ground on the north side of the mill, a concrete dam was constructed 100 yards north of the mill. When completed in September 1913, the dam featured barrels filled with charcoal placed in the far wall of the dam to trap the traces of bullion still contained in the tailings. These yielded $10 per day.[61]

It is possible at this time that the mill capacity was too small and as a temporary measure until further changes took place, pregnant solution from the slimes was only used to enrich the sand leaching. In many ways the changes of the first part of Trojan's ownership were tentative preparations for a larger change in the system, even though the faster decantation sliming method was increasing output over leaching even before these changes took place.

Phase Two, 1917-28

The second phase of Trojan's ownership of the Bald Mountain Gold Mill site was characterized by alterations designed to produce more pulp of a fine slime grade. To this end, ball mills were brought in to supplement the chilian mills, and better use was made of classification. The addition of a secondary thickener system using counter current decantation and an integrated milling/classification system between 1916 and 1925 established the basis of the Bald Mountain Company mill. It also dramatically changed the flow of materials in parts of the mill.

The ball mill consisted of a steel cylinder rotated by an electric motor, acting upon a large gear ring around its circumference. Ore was fed into the mill to be crushed by numerous metal balls as the cylinder was rotated on its axis. Ore was fed in at the axis by a revolving scoop. In the "high level discharge" type, the content simply builds up until it overflows through a tube set in the axis opposite the point of entry. "Low level discharge" mills featured lifting bars attached to the inside of the cylinder which brought material up to a grate at the axis through which it fell.

The first ball mill was installed at the Bald Mountain mill in 1917. It was built by the Denver Engineering Company ("Dewco") and measured 8 feet in length with a 5 foot diameter. It rotated at a speed of 28 RPM and was powered by a toothed shaft driven by multiple belts from a 75 HP motor. This mill was positioned to the west of the primary (chilian) mills and was placed in closed circuit with a rake classifier 6 feet wide, and 18 feet, 4 inches long. Sands from the classifier were carried along a trough by a screw and deposited in the ball mill feed to be picked up by the rotating scoop. Discharge from this mill was by the high level method, and a launder conveyed pulp back to the classifier. This ball mill/rake classifier assembly was itself linked to one of the chilian mills as a secondary milling and classification unit (secondary mill number one). Pulp from the chilian was fed to the secondary mill circuit via the classifier.[62]

When pulp finally left the ball mill circuit it flowed to the elevators which took it to the rake classifiers raised above the sand tanks. These classifiers were now placed in series, one feeding into the other, and became a tertiary classification facility after the primary mills and the secondary milling/ classification machinery. From here sand went down to the sand tanks while slime flowed to the primary thickeners.

Another ball mill/classifier circuit was installed in 1919, replacing the eastern chilian mill and taking over the function of primary mill number one in supplying the secondary circuit. The mill and classifier were raised on large concrete foundations to provide gravity flow for the discharge. The new primary number one ball mill was built by the Allis Chalmers Company. It was 6 feet in length, with cylinder 6 feet in diameter and operated with a low level discharge system. The mill was driven by a toothed shaft powered by a 125 HP, 436 RPM motor acting directly on the mill's gear ring. A Dorr rake classifier 16 feet, 4 inches in length and 4 feet, 6 inches wide was connected in closed circuit and used for primary classification before pulp flowed to the secondary mill/classifier circuit. The eastern of the Challenge feeders was replaced by a timber hopper built onto the base of the 365-ton crusher ore bin to feed the new primary mill number one by an 18 inch-wide belt conveyor.[63]

Mill solution was added at the discharge end of the primary ball mill from the mill solution tanks (a second was added beside the first), and at the feed end by an extension of the pipe from the primary thickener overflow. This overflow also supplied the remaining chilian mill (primary number two) and the other (secondary) ball mill. Pulp from the secondary mill flowed through a launder to the bucket elevators where, with the output from primary mill number one, it was raised to the secondary classifier platform.

In 1917, a Weigand Classifier was installed on a platform adjacent to that of the two rake classifiers and was receiving pulp by bucket elevator from the grinding circuit as well as mill solution from the storage tanks. The Weigand was circular in shape with a 8 feet, 6 inch diameter bowl in which rotary rakes at the bottom discharged settling sands. The flow of solution removed lighter slime particles at the top. Although the power source for the Weigand classifier is unknown, a motor driving a central shaft via bevel gears or line shafting is possible. The rake and Weigand classifiers together acted as a tertiary classification unit, taking pulp from the secondary below sending sands to the sand tanks while the slimes flowed to primary thickener number one. Both these routes used gravity and required no pumps.[64]

Also in 1917, a second primary thickener and a secondary thickener system composed of three tanks were built.[65] To accommodate primary number two, the fine grinding floor was further extended to the west and south. The sand tank level was extended to the west by six bays and then south next to a retaining wall at the edge of primary 2. The new primary thickener was of the same dimensions and similar construction as the first, with high concrete piers supporting heavy timbers to raise the tank above the underflow pipe and provide useable inclines for gravity flow.

Overflow solution from primary thickener number two joined that from number one to be reused in various ways. It could be sent back to the mill solution storage tanks, or into the grinding system, either to primary mill number two (the chilian) or the secondary mill/classifier. In this way an excess of solution output could be diverted from the limited capacity of the gold tanks and precipitation facilities by being sent into the fine grinding circuits for further enrichment.

Primary thickener overflow that was sent to precipitation was first passed through a "gravity clarifier" set on timber staging just below the thickener discharge launders. This clarifier removed solids from the overflow before joining solution from the sand tanks on its way to the gold tanks. The name implies a simple filter through which solution passed, although the remains of line shafting are still seen at floor level (incorrectly placed for thickener drive), and the presence of a 15 HP gasoline engine suggest it may have had some form of compression action built in. By 1925, the gravity classifier was no longer connected to the thickener outflow, improvements in the precipitation floor having made it redundant. The underflow pulp from the primary thickeners discharged through a connecting pipe to the agitator series where it underwent continued cyanidation.[66]

In 1917, two more agitators were constructed at the western end of the row, in vacant space that was probably intended for that purpose. At this time the flow of the agitator sequence was reversed (east to west) and the height of the tanks and their discharge launders altered, creating gravity flow to the secondary thickeners. Three secondary thickener tanks were constructed in the six new bays at the western end of the sand tank level, the end three of which extended south beside a retaining wall at the edge of primary thickener number two. Each tank was of the same dimensions and construction as the primary thickeners. They also operated in the same way and were driven by 10 HP motors fixed at the top of the central plough/arm shaft.[67]

A counter current decantation system was used in the secondary thickeners. Slime was passed from agitator number five to secondary thickener number one, the solids from which were then drained from the bottom and pumped up to number two by a pair of four inch diaphragm pumps. In secondary thickener number two the underflow slime was transferred by another pair of four inch diaphragm pumps to the third tank, where it was finally discharged to flow back downhill to the filters. While the solids were moving uphill they came into contact with barren cyanide solution that had flowed down from the barren solution storage tank. This solution became pregnant solution (bullion bearing overflow) and was transferred, without the aid of pumps, from secondary thickener number three to number two and number one before flowing to the Butters filter and then to the gold tanks.

To undertake the heavy work of filtering slime from the secondary thickeners, three Portland filters were installed in 1917. Two were located on the western half of the precipitation floor and an extra bay was added to accommodate the third. While the exact operation of these machines is unknown, from a photograph and contemporary description they were clearly a form of rotating drum vacuum filter similar to the Oliver design. Fabric filters were attached to the outside of a rotating cylinder and a vacuum created behind the filter. The lower part of the cylinder was immersed in a pulp bath, and as the drum rotated, pulp was spread against the filters. The vacuum sucked solution through the filters, leaving solid "cake" on the outside to be scraped off by a blade fixed against the cylinder. The drum revolved on two trunnion bearings and was powered via a worm gear drive. Examination of the remaining foundations shows the Portland filter cylinders were orientated east-west, with the feed troughs supplied from the south side and cake probably deposited on the north. A vacuum receiver 8 feet high and 4 feet in diameter powered by a vacuum pump drew the filtered solution from the filters, and a Triplex pump of 4 inch bore and 5 inch stroke transferred it to the mill sump.[68]

To accommodate the extra output of pregnant solution, four extra zinc boxes were added around 1918.[69] Three were of the same dimensions as the existing three, but one held compartments of slightly over half width. An extra bay was built onto the east side of the precipitation floor to house them and all fed by gravity into the barren solution sump below the floor.

In the clean-up room, in addition to an acid tank for the cleaning of filters, two filter tanks, a settling tank and a sump are shown in 1925.[70] It is possible these were used to collect solids from the filters, perhaps to reclaim any last metallic value they might have. No details of the refinery are known during this period, but it can be assumed that the new oil-fired furnace was installed, (accounting for the construction of an on-site oil store), to handle the increased production of precipitate.

A Trojan Mining Company site plan of 1915 (BHSUL) shows the extent of new facilities the above changes had necessitated in the ancillary buildings. On the hill behind the mill a pair of octagonal roofed water tanks stored water pumped from the Two Johns mine for use in the mill. A stable was constructed on the south side of the tramway to accommodate mine horses. A machine shop was built east of the crude ore bins. Both crude ore bins were extended on the east and west sides, the latter enclosing the track from the Eagle mine and abutting the ore bin covering snow sheds erected around 1912. Behind the east end of the shop a coal depot building and truck garage was built to take coal from the road and place it into mine cars. A lime bin was constructed beneath the ore drops on the west side of the main crude ore bins, making delivery by rail possible. To the east of the mill, a hoist house pulled cars up and down an incline to a coal-fired boiler house that provided heating for the mill. One branch of this incline connected with the refinery and precipitation floor while another led across the base of the ore bin/ mill conveyor to a repair shed, immediately to the northwest of the bins. This shed stored repaired bearings for both mine and mill use. The refinery, assay office and electrical substation remained in their original positions.

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Two major developments took place at the mill during the ownership of the Bald Mountain Mining Company. First, production was changed from part-sand to all sliming. This technological change involved extra crushing facilities and an enlarged secondary thickening circuit. Pulp could then be subjected to increased cyanidation. Second, a successful method of preparing refractory unoxidized (blue) ores for cyanidation was applied, initially in a small pilot mill and then in a full scale blue ore roaster circuit. This circuit added a lateral branch, or spur, to the main flow of material through the mill, though part of it was still housed within an extension of the main building. Discussion of these changes can be divided into the blue ore system itself and the various other changes to the mill, most of which took place in the early part of the Bald Mountain Company's ownership, from 1934 to 1940.

A magnetic head pulley manufactured by the Ding's Magnetic Separator Co. of Milwaukee was installed at the mill end of the main conveyor in 1938. This device consisted of a drum, measuring 24½ inches wide and 24 inches in diameter, that acted as the end winding drum at the head of the conveyor. It was electro-magnetically charged by a motor-generator set driven by a 3 HP, 1800 RPM motor connected by chain and sprocket drive. Ore passed over the head pulley and ferrous materials adhered to the belt as it came into contact with the magnetic drum. The ferrous materials were released, dropping onto a chute and collection bin, only when the belt passed out of the magnetic field.[71]

A 3 feet wide, 6 feet long Symons horizontal single deck vibrating screen with ½ inch space mesh was placed at the top of the conveyor from the ore, also in 1938. Larger pieces of ore were moved off the screen by its rocking motion and fell down a chute into a newly installed secondary coarse crusher situated on the ground floor below, while smaller particles fell through the screen and were taken, via a chute, to a reversible belt conveyor. The secondary coarse crusher installed that same year was gyratory type 3 feet in diameter, manufactured by Symons. It was driven by a 60 HP motor and set on massive concrete foundations above a 24 inch belt conveyor taking the crushed rock discharge to the foot of a bucket elevator.[72]

Smaller grade ore on the reversible belt conveyor could go in two directions. One deposited ore into the dryer. The other direction took small pieces of ore to the base of the 24 inch belt conveyor below the cone crusher, thus carrying the material underneath the crusher and by-passing it. At the end of this conveyor a 42 feet high bucket elevator was installed in 1938. It was manufactured by Stephens-Adamson of Aurora, Illinois, carried 25 tons per hour at a rate of 144 feet per minute, and was powered by a 5 HP, 1730 RPM motor via chain and sprocket.[73] At the top of the elevator, an 18 inch belt conveyor led to the 365-ton ore bin.

The installation of this secondary coarse crushing facility and the roaster circuit prompted the addition, in December 1939, of a dust collecting system. A 28 foot, 6 inch high dust collecting tower with a maximum diameter of 9 feet, 7 inches and a conical bottom section was placed against the east wall of the 365-ton crushed ore bin. Dust was collected from the Stephens-Adams bucket elevator, secondary coarse crusher and adjacent belt conveyor plus the mill, screen, cooler and inclined bucket elevator used in the blue ore system. Metal hoods secured these machines as dust was drawn into the collector through overhead steel pipes by a 4 foot Norblo fan housed on top of the collector tower. The fan was driven by a 25 HP, 1800 RPM motor connected by rope drive. Approximately 80% of the dust was filtered out before the air was vented through a four foot stack.[74]

In 1946 a new primary coarse crusher was installed. Manufactured by the Traylor company, the new jaw crusher was 15 by 24 inches in diameter and powered by a 50 HP motor. Jaw crushers worked by the action of a hinged crushing surface pressing ore together. The distance between the two determined the grade of crusher rock produced, in this case 1 3/8 inch. The main conveyor from the primary coarse crusher and ore bins was changed from 18 to 24 inches in width and shortened as housing for new crushing and screening equipment brought the top level of the mill building further back into the hillside.[75]

On the milling floor, major changes took place in 1935. Another ball mill/classifier circuit was installed and the remaining chilian mill removed. The tertiary rake and Weigand classifiers and their platforms were also removed. Primary mill number one (the new ball mill classifier circuit) and primary mill number two (the existing one) both fed their slime output to the secondary mill circuit (the third in line) for further milling and classification while keeping their sands in closed circuit until fine enough for discharge. Primary mill number one was a Stearns Rogers machine, 6 feet in length with a cylinder 6 feet in diameter. It rotated at 24 RPM by belt drive from a 125 HP, 880 RPM motor and discharged by the high level method. The attendant Dorr rake classifier was 6 feet wide, 18 feet long and linked to the ball mill by sloping launders at either end. Crushed brown ore was delivered from an 18 inch wide belt conveyor connecting the western of the 365-ton ore bin hoppers while blue ore came from a launder running beneath the mill solution tanks. Both fed into the launder at the sand discharge end of the classifiers. Mill solution entered the circuit at the ball mill feed from the mill solution storage tanks, which had a surge tank added for extra capacity at about the same time.[76]

The classifier in the second primary milling circuit was replaced in 1935 by another Dorr rake machine 18 feet long and 6 feet wide, directly driven by a 3 HP, 860 RPM motor. Slimes from the two primary mills reached the secondary mill circuit in a wood launder, via a new 4 foot by 4 foot surge tank. Also in 1935, the secondary milling circuit benefitted from the replacement of its rake classifier with a Dorr rake and bowl classifier. The bowl classifier was a steel bowl reinforced with a concentric steel band inside the rim, set above the slime discharge end of a standard rake classifier. Pulp was delivered into a feed well around a central drive shaft, powered by a bevel gear system from above, situated in the center of the bowl. This shaft drove rotating arms in the bottom of the bowl, each with a set of small ploughs. These ploughs moved heavier solids (ie: sands) towards a central drain which discharged into the rake classifier trough beneath. Slimes, light enough to be kept in suspension, flowed over the lip of the bowl and were borne away in a launder.

The bowl classifier used at Bald Mountain was 18 feet long, 6 feet wide, and had a bowl 10 feet in diameter in which the arms rotated at 3/4 RPM. Sand deposited in the rake classifier was moved to the top and returned to the ball mill circuit by a screw conveyor in a wood trough. It was then moved to primary thickening by a pair of 4 inch bore pumps. These pumps were manufactured by the Wilfley company and driven by 25 and 15 HP motors.[77]

The new milling floor arrangement enabled more alternate milling sequences to take place and a finer end product to be produced, due to the more discriminating action of the bowl classifier. In practice maintenance, or an easily milled ore sometimes led to the shut down of one primary, which was easily by-passed. The new milling facilities heralded a change to all-slime production and the removal of the sand tanks. However, a reference to changing to full counter current decantation in 1939 implies that at least some sand leaching continued until this date. After the construction of additional secondary thickeners, and the secondary classifiers Wilfley pumps only two sand tanks could possibly have been in use but there are no documents to confirm or deny this.[78]

The operation of the primary thickeners remained much as it was during the Trojan period. Overflow from the primary thickeners could be returned to the primary ball mills or flow down to the gold tanks, where a 4 foot by 4 foot surge tank was added for excess liquid. Another surge tank, measuring 7 feet deep and 7 feet in diameter, was placed on a timber platform near the primary thickeners, where the gravity classifier had been.

This tank received any excess thickener overflow before releasing it to either of the two destinations. Underflow from the primary thickeners flowed to the agitator sequence where it moved east to west.

Three new secondary thickeners, forming a counter current series independent from the first, were fitted in 1936.[79] They were 24 feet wide, 8 feet deep and of common steel tie-bound timber stave construction raised on concrete piers and powered by individual motors. By siting the new series in the western seven bays of the original sand tank floor, the thickeners took the place of sand tanks four, five and six. Pulp leaving the agitator series was divided between the two secondary thickener series, beginning with number one (the "old" series) or number four (the "new" series). The two series operated as mirror images of each other so that thickened underflow from number one was pumped uphill through number two to three, while underflow from number four was pumped via five to number six. Diaphragm pumps of 4 inch bore were installed in the new series to move pulp uphill. Once it had reached the end of the respective series, the pulp was allowed to flow back to the Portland filters where it was diluted with water ready for filtration. As the pulp made its way up the secondary systems barren solution was brought into contact with it while coming down the series. Barren solution from the barren solution tank was introduced to secondary thickeners numbers three and six and flowed down hill to numbers one and four respectively. From there it overflowed into the mill solution sump.

In the fall of 1939, a seventh secondary thickener, constructed of laminated wood three feet thick, fifty feet in diameter and twelve feet deep, was situated at the western edge of the mill. Adjacent to secondary thickener two, it was located in a semi-free standing 13-sided shed. Drive for the rakes was supplied by a 2 HP, 1750 RPM motor with a speed reducer mounted over the center shaft.[80] Once operation began in 1940, secondary thickener seven received pulp pumped uphill from the top of the two secondary thickener series (thickeners three and six) by a 4 inch bore duplex diaphragm pump. After thickening overflow was returned to the old series at number three while the underflow was diluted with water and pumped to tailings by a 3 inch bore Wilfley.

By 1954, three 'fine tuning' adjustments had been made.[81] To limit the amount of agitation the pulp underwent, and therefore the amount of oxygen the precipitation process had to contend with, a bypass was installed so pulp could leave the agitator series at tank number four. At agitator five itself, another by-pass was constructed enabling the whole counter current process to be avoided and pulp to be channeled directly to the seventh secondary thickener. This by-pass was probably used to remove exhausted pulp from the system without the trouble of further thickening. An additional bypass allowed the underflow from secondary thickeners three and six to be returned to agitator five.

The major change in the precipitation section was the removal of both Portland filters and zinc boxes and the installation of new equipment using the Merill-Crowe vacuum process. A pair of vacuum leaf clarifying tanks replaced the filtering action of the Portland and Butters' filters. An oxygen removal stage was added, enabling zinc more effectively to act as a precipitant. The first tank was installed in 1934, measuring 12 feet wide and 8 feet deep, the second, 10 feet wide and 8 feet deep, after 1936.[82] Both tanks were constructed of timber staves bound with steel hoops and contained 17 or 10 filter leaves respectively, 7 feet by 5 feet in dimension. The fabric leaves were reinforced with wood slats, and stretched across a perforated tubular frame. A solution inlet valve kept the level constant, and the leaves entirely submerged to prevent air being drawn in. An Ingersoll Rand vacuum pump created suction in the tubular frames via a receiver tower, pulling solution through the leaves, while the solids were left on the leaves. A second valve controlled solution outflow from the tanks to maintain pressure within the receiver chamber. The solution was broken up into fine streams by wood slats as it fell through the receiver, enabling the air to be removed while the de-oxygenized solution, settling in the bottom, was pumped out.

An emulsion of zinc dust was introduced (at the rate of

0.025 pounds per ton of solution) to a fraction of the liquid diverted from the main flow and then returned.[83] A small belt conveyor supplied zinc dust to a feeder cone that introduced it to the solution while passing through a liquid-sealed pump. Precipitate was retrieved from the now barren solution by pumping it into two tanks containing 60 cylindrical filter bags each, submerged in solution. Precipitate remained in the bags while the barren solution was pumped up to the barren solution tank. The precipitate was removed from the bags and taken for refining.

The mill and barren solution sumps beneath the precipitation floor were removed, probably in 1934 during the alterations to the precipitation machinery, and replaced by a trio of concrete tanks. The easternmost of these, the mill solution sump, received solution directly from the secondary thickener series. Solution was then pumped back to the mill solution tanks by a Triplex pump of 8 1/4 inch bore and 10 inch stroke. The middle sump acted as an emergency overflow from the first and solution from both was removed by another pump. The third sump, beneath the western side of the precipitation equipment, served as a mill drainage sump for material drained from the secondary thickeners and agitators through a system of concrete channels set in the mill floor. A Triplex pump of 7 inch bore and 8 inch stroke removed solution to the mill solution sump. A cyanide feeder tower was constructed above the mill drainage sump. This tower was a simple timber structure with a hinged chute to pour cyanide into the sump below.

In the refinery during this period, the drying oven was a large brick structure with three compartments for trays of precipitate and fire doors at ground level, stoked with wood. The small melting furnace had two gas fired compartments and was of steel, presumably with a firebrick lining. A pouring melting furnace was also used, so bullion could be poured into molds by a gas fired container mounted on trunnions. An additional alteration to Bald Mountain mill was a second dam built in 1934 to retain seepage from the existing one about one mile north of the mill. The water collected there was pumped back to the mill's water tanks for reuse.[84]

Although the higher grades of refractory unoxidized ('blue') ores from the Bald Mountain region had long been transported to specialized custom smelters, much of the lower grade resources were untouched. Many deposits would only yield about 11% of their potential value in gold and silver by the cyanidation process and the blue ores from the Two Johns mine could yield as low as 7% from orthodox grinding and cyanide action. It had long been understood that additional preparatory processes would be required to improve this situation. Experimentation at the South Dakota School of Mines in 1927 encouraged the Bald Mountain Company to institute a pilot roaster project on site in 1935. The pilot mill was constructed to the east of the main mill building, beside the tramway incline for transporting ore to the boiler house. An initial estimate foresaw recovery rates of 85-87% from ore milled to 200 mesh. A trial run from January 23 to March 26, 1935 used both Two Johns blue ore and Portland brown ore to compare the performance of the machinery. First results showed recovery at 73%.[85]

In order to process small amounts of ore under completely controlled conditions, the pilot facility was developed into a scale model of the whole mill process, with the exception of refining. Rather than one downhill linear flow, two parallel flows on three terraced levels were used. The first, housed in the eastern side of the building, contained the crushing and roasting machinery. The roasted ore was then returned to the top of the pilot mill, where it underwent grinding and cyanidation, in imitation of the mill itself. From mine cars, ore was dropped into a bin where it could be released onto an area of sheet metal floor inside the building. From surviving evidence it appears that it was then sorted by hand into one of two chutes. The larger material fell into a jaw crusher and from there to a vibrating screen on the second level. The finer material passed straight down to a roller mill parallel to the screen. All these machines were run by belts from line shafting. A bucket elevator took ore from the screen and rolls. It is unclear what happened to material too big for the screen, but it may have been manually transferred to the rolls. The bucket elevator deposited ore in a timber bin on the third floor where a belt conveyor carried it to the roaster.

Early experiments centered on the inadequacies of the commercially available roasters of the time and for the first test a "blast kiln type furnace" was used. A customized rotary hearth design was constructed for the Bald Mountain Company. This machine consisted of a circular firebrick tunnel within which a steel hearth rotated, driven from beneath. Heat was provided by gas burners set in the walls and ore was agitated to ensure even roasting by sets of rotating blades called "rabbles". One advantage of this design was that the rotary hearth allowed greater control over temperature and length of roasting.

The roasting hearth was 3 feet wide and 32 feet in circumference. The rabbles were driven by 18 meshing cogs arranged around the roaster roof. Two sets of bevel gears, running from a motor, drove the rabbles via these cogs, through the roof, and onto the hearth. Discharged ore left the hearth by a rotating scoop moving it into a screw conveyor which deposited it into a bin or mine cars.[86] At the top of the second part of the mill roasted ore was deposited into a ball mill. From this point most of the machinery no longer survives but it seems that ore pulp flowed past two tanks (possibly cyanide solution) to a pair of steel tanks, linked by launders and served by overhead line shafting. These were probably thickeners. There does not appear to be any sign of agitation machinery but that does not discount its presence. From the tanks ("thickeners") solution probably flowed to the Dorrco rotary vacuum filter that is still extant. Solids fell into a tank built below the roaster and liquid was collected in a small tank. Where and how precipitation took place is unknown.

The construction of a full scale roaster was largely carried out in 1939, though the blue ore preparation facilities included secondary coarse crushing machinery that had been installed prior to that. Quantities of blue ore were put through the mill separate from brown ore in order to isolate them and monitor the processing procedure and its effects. Additional machinery was required to divert ore to the roaster, for preliminary drying, extra crushing, screening and storage. The new roaster circuit was housed within the secondary crushing building behind (south of) the 365-ton crushed ore bin, and partly in an additional building constructed adjacent to it. The roaster itself, and its attendant cooling and storage facilities were set outside the main mill building.

Although a relatively self contained processing arrangement, the roaster circuit forms a branch along which ore was diverted before rejoining the main current of movement within the mill. Processing of blue ore started from the main crude ore bins at the head of the conveyor. As the larger pieces of crushed blue ore passed over the Symons vibrating screen, they were directed via a chute into the same Symons 3 foot gyratory secondary coarse crusher used for brown ore. Smaller particles which passed through the vibrating screen were deposited on a reversible belt conveyor. This belt fed blue ore to a Stearns-Roger cylindrical dryer 4 feet by 20 feet, fitted with feed and discharge hoods. A gas burner at one end heated ore as it was moved along the inside of the cylinder revolving on motor driven rollers. Exhaust heat from the dryer was removed by a steel tubular stack 44 feet high, 24 inches in diameter supported by guy cables, situated outside the mill building and connected by a horizontal flue. The exact nature of the reversible conveyor's connection with the dryer is unclear. It is likely that the conveyor arrangement was altered when the dryer was removed some time after the cessation of blue ore processing in 1942, thus making an assessment based on existing remains difficult.[87]

The method of discharging ore from the dryer is also open to question, although illustrations show a 9 inch cast iron screw conveyor with an 11 foot shaft in position at the discharge end of the dryer. Drive was provided by a chain and sprocket arrangement and the screw operated at 30 RPM.[88] Dry ore, having previously passed the Symons Screen, was passed by a 24 inch belt conveyor directly to the elevator feed.

Large ore pieces, after passing through the secondary coarse crusher, moved on the 24 inch belt conveyor, along with material from the dryer, to the Stephens-Adamson 42 feet bucket elevator. This elevator took the ore to the upper floor where a manually operated gate was used to divert the blue ore straight from the elevator to a newly installed 100-ton steel ore bin. This bin measured 15 by 15 feet with a conical cover, side walls of 3/16 inch and base of 5/16 inch sheet steel. Blue ore was fed from the 100-ton bin by a 18 inch belt conveyor to a 3 feet wide, 8 feet long Symons vibrating screen with an mesh screen, rope driven by a 3 HP, 1800 RPM motor. Material too large to pass through the screen was shaken from the top and conveyed to a new Stearns-Roger rod mill. This mill operated like a ball mill but included long steel rods in the milling cylinder. It was 4 foot in diameter, 8 feet in length and powered by a 50 HP, 720 RPM motor situated at the discharge end. The rod mill went into operation in January 1939.[89]

Fine ground material from the rod mill was discharged into a 12 foot long screw conveyor motor 12 inches in diameter, driven by chain and sprocket drive. From this screw conveyor, an inclined bucket elevator was installed to take the ore back up, depositing it in the screen where oversize was retained for further rod milling. Once the ore had reached the required size it left the screen for the roaster building by a 14 inch wide belt conveyor, 48 feet long and driven by a 5 HP, 104 RPM motor. A bucket elevator at the end of this conveyor deposited ore into a 50-ton capacity steel ore bin built alongside the roaster. The 50-ton bin was 12 feet in diameter, 10 feet high and was constructed with 3/16 inch steel sheet sides and 5/16 inch steel sheet base. The top was conical and the discharge door built with a rack and pinion system securing it. A small bucket on chains rotated in front of the bin feed-in point, taking ore samples for assaying.[90]

The octagonal roaster building was constructed on a poured concrete foundation with a floor of compacted soil. Concrete construction was also used in the base of the walls, with steel framing for the upper parts. The roof and upper walls were clad in corrugated sheet metal. The roaster's hearth was basically a large, flat steel ring, 50 feet, 4 inches in diameter outside, 26 feet, 3 inches inside and 12 feet, 1 inch wide with 2 inches of concrete and 4 inches of insulating material on its upper face. The roasting surface totaled 1,400 square feet, although approximately 53 square feet were taken by the charging and unloading mechanisms. The hearth was rotated by an electrically driven gear wheel acting on a loop of heavy chain. This chain connected with lugs built onto rails beneath the hearth. The hearth was also supported by a separate set of rails resting on unpowered rollers beneath it. Power was supplied by a 5 HP, 1730 RPM motor and a complex series of gears.

Ore was deposited evenly at a depth of between 1 inch and 5 inches and heated by natural gas burners set in the walls around the heating part of the circuit. The part closest to the charging and discharging apparatus was unheated, allowing ore to warm and cool during the cycle. Temperature varied with the condition of the ore and its position within the roaster, but a maximum of 1120 degrees Fahrenheit could be achieved. As the hearth rotated the ore was stirred in order to make the roasting more even. The stirring was done by sets of plows on rotating arms positioned just above the hearth. There were 13 plow and drive shaft assemblies, called rabbles, with up to 8 plow blades each (less in the heated part of the circuit), rotating at 10 to 40 RPM. They were placed symmetrically around the hearth circle and driven from overhead by solid shafts and bevel gears from a 15 HP, 1500 RPM motor filling the 14th place in the circle.

The hearth was enclosed in a 9 inch thick firebrick tunnel (with 2 ½ inches of additional insulation on the walls and 3 inches of plastic asbestos on the roof). The tunnel was built over the hearth from foundations on either side, leaving the hearth free to rotate independently within it. Fumes and heat could be drawn off through a 150 feet tubular steel stack outside the roaster building built by Stearns-Roger. The stack had a diameter of 42 inches, weighed approximately 14-tons and was constructed from 1/4 inch steel plate. It was erected on January 23, 1940, replacing an earlier stack 48 inches in diameter and 150 feet high that stood nearby.[91]

A Baker Cooler was installed in September 1938 to cool the ore that was taken from the roaster by an eccentrically rotating scoop feeding a screw conveyor. The cooler consisted of a horizontal steel cylinder 5 feet in diameter and 40 feet long with a screw inside. As the cylinder was rotated in a trough of coolant water, ore was moved along inside. Power to turn the cooler was supplied by a 7 ½ HP motor operating at 1740 RPM, protected from the water and fan cooled. The motor drove the cylinder by acting on a large external gear wheel around the circumference of the cylinder which rotated at 20 RPM.[92] Pulp was fed from the cooler to rejoin the main process of the mill operation at the ball mill circuits. Mill solution was introduced to the pulp as it flowed in a trough beneath the mill solution tanks.

Few additions or changes were made to the mill's ancillary facilities during the Bald Mountain Company period. The machine shop was extended to the north with the inclusion of a small furnace building, while the coal depot and garage adjacent to it were demolished. Further to the east of the mill, a hopper was installed linking the road to the tramway and coal was presumably transferred to mine cars at that point. An additional concrete water tank, capable of holding 100,000 gallons, was built on the hillside south of the mill complex, and the electrical sub-station was moved further to the east of the mill when the roaster building was constructed.

CHAPTER SEVEN: CONCLUSIONS

By observing the development of the Black Hills gold fields and specifically the Bald Mountain district, the origin of the Bald Mountain mill in the growth of small, independent hard rock mines and their need for custom milling facilities is shown. The Bald Mountain district construction (or adaptation) of mills and their positioning at the center of integrated multi-mine industrial complexes was made possible by the application of increased amounts of capital and the organization of large companies in the Black Hills. The various ownership periods of the mills illustrate the stages of development of Black Hills gold field mining.

The Eagle Company appears to have run a small scale, financially vulnerable operation using slow and relatively primitive technology (sand leaching) with little capital, or perhaps opportunity, to expand and improve. The Trojan Mining

Company took over the mill with a view to developing an integrated processing facility that would reduce their reliance on outside contractors. The concurrent increase in mine productivity encouraged the adoption of sliming technology that would both improve recovery and increase the volume of material handled. The result was a part-sand, part-slime hybrid mill with two distinct flows, diverging at the milling stage and converging at the filtration/precipitation stage. The Bald Mountain Company completed the change to all-sliming production and introduced the roasting of blue ores on a large scale to counteract the decline in high grade ores at their other properties. The roasting operation utilized the improved crushing facilities already installed to make an overall improvement in the crushing of ores, while classification of slimes became a more refined process.

Throughout these changes, continuities in succeeding generations of gold milling technology influenced the basic layout of the mill, a structure which takes its very form from the fundamentals of the milling process. Changes in the fortunes of the mill's owners marked major technical changes. The mill's owners were "not always well capitalized or endowed with ore reserves" and in many cases they were responding to circumstances beyond their control. Unlike many other mines, the Trojan and Bald Mountain Company properties were both separated geographically, and liable to produce ores of dramatically differing characteristics which were often only of lucrative value for relatively short periods of time. Add to these factors the innate problems of a highly volatile industry very much at the mercy of governmental policy and fluctuations in the wider economy, and it becomes clear that the Bald Mountain mill was in a rather difficult position for most of its turbulent career. The physical remains of this business endeavor testify to the complexity and extent of the efforts to profit from the gold of the Black Hills.

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ENDNOTES

Abbreviations used:
BHSUL (Black Hills State University Library)
BMMC (Bald Mountain Mining Company)
HMCA (Homestake Mining Company Archive)
SDSML (S. Dakota School of Mines Library)
TMC (Trojan Mining Company)
UECCA (United Engineering and Construction Co. Archives)

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